

Supercapacitive properties of Electropolymerized Poly(3,4-ethylene dioxythiophene) and Poly(aniline) Co-polymer electrodes

In this paper a co-polymer of polyaniline (PANI) and Poly(3,4-ethylenedioxythiophene) PEDOT films with different molar ratio (MR) were electrochemically deposited by cyclic voltammetry and short current pulse onto glassy carbon electrode from micellar solution. The surface morphology of the resulting co-polymer films was characterised by scanning electron microscope and the effect of monomers molar ratios on capacitive property were characterised using cyclic voltammetry in acidic and neutral solutions. The specific capacitance of the PEDOT-PANI co-polymer reaches up to 327 F g^{-1} and retains about 90% from original value after 300 cycles in $1.0 \text{ M H}_2\text{SO}_4$ at 10 mVs^{-1} . Presence of sodium dodecyl sulphate (SDS) enhanced the co-polymer capacitance and decreased the polymerization potential of the monomers. The polymer composites show improved capacitance stability in neutral solution (1.0 M NaCl) as well as in acidic solution which reflects the synergism between PANI and PEDOT of the co-polymer deposit.

Key words: Conducting polymers; Electron microscopy; Electrochemical properties; Supercapacitor.

1. INTRODUCTION

Electrochemical capacitors are an increasingly important class for energy storage devices [1, 2] that are able to absorb and release charge much more quickly. The characteristic redox activity of conducting polymer is regarded as the basis for many applications in field of electrocatalysis, electron transfer mediation, and energy storage [3, 4]. Electrochemical capacitors are high density charge-storage devices and exhibit excellent reversibility with a long life cycle [5]. The energy stored in these devices mainly comes from either the electrical double layer or the pseudocapacitance of electroactive materials [6].

Many materials are used to fabricate the supercapacitor electrode materials such as carbon [7], RuO_2 and NiOx [8, 9]. Conducting polymers of polyaniline (PANI), polypyrrole (PPY), Poly(3,4-ethylenedioxythiophene) PEDOT [10] and polythiophene are widely used as electrode materials for supercapacitors applications. This is because the redox process is used in conducting polymers to store and release the charge. When oxidation occurs, ions are transferred to the polymer backbone and in case of reduction the ions are released back into the solution. Therefore charge-discharge process in conducting polymer films takes place throughout the bulk volume of the film and not just on the surface. This offers the opportunity of achieving high levels of specific capacitance [11].

Poly(3,4-ethylenedioxythiophene) (PEDOT), polyaniline (PANI) and their derivatives have the advantages of greater chemical stability among the other organic conducting polymers [12, 13]. Polyaniline (PANI) has received a great attentions due to its advantages of being easily synthesized, environmental stability, and higher energy storage [14-17]. However PANI has the drawback of degradation at high potentials and unstable in neutral solution which restricts its use in field of supercapacitor [18].

An improvement in the properties of the polyaniline electrode in an aqueous electrolyte has been realized by incooperating polyaniline into a composite with Nafion [19] and also by copolymerisation with aromatic phenylenediamine [20-24]. Copolymerization is often used to prepare a new polymer with properties that differ from the constituent homopolymers. Generally, the physical and chemical properties of the co-polymer are intermediate between those of the respective homopolymers but significantly distinct from those of the composite and blend. Recently copolymers of aniline and m-phenylenediamine with different molar ratios were synthesized by a chemical oxidation method [25]. The obtained copolymers exhibited the initial specific capacitance value of 475 F g^{-1} and show improved cycling performance and stability.

PEDOT/PANI co-polymer modified electrodes have received a great attention as an electrode material because it exhibits interesting properties in light emitting devices [26-29] and in electrochemical catalysis [30-32]. The using of PEDOT/PANI co-polymer as electrode materials for supercapacitors has the advantages of long life cycle, low cost of manufacture and high energy content with respect to volume and weight. The quality of the deposited polymer on the

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electrode has been shown to be strongly dependent on the experimental conditions such as solvent, dipping time, electrode surface state [33], monomer structure, electrolyte, polymerization potential, electropolymerization method and concentration. All of these parameters having profound influences on the structure and the electrochemical properties of the resulting polymers.

In a recent work we prepared polyaniline (PANI)/polyethylenedioxythiophene (PEDOT) co-polymer electrodes with molar ratio of 1:1 by simultaneous electrochemical polymerization of ANI and EDOT monomers. The resulting polymer film showed an electrochemical activity towards ascorbic acid oxidation and specific capacitance reaches up to 260 Fg^{-1} [34]. In this work we investigate in details the electro-deposition of PANI/PEDOT co-polymer with different molar ratio onto glassy carbon electrode using cyclic voltammetry and current pulse techniques from aqueous solution containing different monomer concentrations. The co-polymer morphology was characterised by scanning electron microscope and the specific capacitance was measured using cyclic voltammetry in acidic and neutral electrolytes. The presence of surfactant during electropolymerisation enhanced the capacitance and improved the copolymer stability in neutral and acidic solutions.

2. EXPERIMENTAL

2.1. Materials

The monomer 3,4-ethylenedioxythiophene EDOT was purchased from Bayer Company and aniline from Aldrich. Sulphuric acid 98%, sodium chloride and sodium dodecyl sulphate (SDS) were provided by El-Nasr Pharmaceutical Chemicals (ADWIC, Egypt). All solutions were prepared using deionized water (resistivity $18.0 \text{ M } \Omega \text{ cm}$).

The working electrode was made from a glassy carbon disk 3.0 mm diameter (SIGRADUR, Germany) by sealing 1.0 cm long x 3.0 mm diameter GC rod in glass tube and connected by copper wire using melted indium (Aldrich). GC working electrode was polished with alumina powder (1.0 and 0.5 μm) to a mirror finish, then sonicated in water to remove any residual alumina particles and dried in air before use.

2.2. Electropolymerization and characterization

All electrochemical experiments were carried out using SP-150 Potentiostat/galvanostat (BioLogic) connected to a computer with EC-Lab software. The electrochemical cell was a conventional three electrodes system with a platinum mesh as the counter electrode and a saturated calomel electrode (SCE) as the reference electrode. The aqueous solution used for

the polymerization contained 0.5 M H_2SO_4 as supporting electrolyte and 70 mM SDS as surfactant. The total monomers concentrations were 50 mM with different mole fraction from EDOT and ANI as shown in table 1 below.

Table 1 - Solution molar ratios of EDOT and ANI used for the co-polymer electrodeposition.

Mono-mers	P1	P2	P3	P4	P5	P6	P7
EDOT/ mM	50.0	45.0	35.0	25.0	15.0	5.0	0.0
ANI/ mM	0.0	5.0	15.0	25.0	35.0	45.0	50.0
X_{ANI}	0.0	0.1	0.3	0.5	0.5	0.9	1

Prior to each experiment the solution was purged with nitrogen gas for 20 min to remove any dissolved oxygen. Polymerization was carried out at GC electrodes by cycling in the potential range from -0.4 to 1.2 V vs. SCE at scan rate of 50 mV s^{-1} .

For polymerization solution with a molar ration of $X_{\text{ANI}} = 0.7$ and 0.5 M H_2SO_4 as supporting electrolyte and 70 mM SDS as surfactant deposition was carried out also at constant current of 0.4 mA pulses for a very short period off time. Pulse on time was 10 ms and pulse off time was 100 ms no current was applied during off period. Numbers of on pulses were 15,000 the total growth time was 150 s. also DC polymerization was carried out for the same solution composition using 0.4 mA for 150 s.

The resulting polymer films were characterized by cyclic voltammetry in 1.0 M H_2SO_4 and in 1.0 M NaCl aqueous solution and the scanning electron microscopy, SEM, (JEOL 6400) was used to study the film morphology.

3. RESULTS AND DISCUSSION

3.1 Electropolymerization of EDOT and ANI mixed monomers using cyclic voltammetry.

Fig. 1 shows a series of multisweep cyclic voltammograms of GC electrode in 0.5 M H_2SO_4 and 70 mM SDS micellar solution and containing different molar ratio of EDOT and ANI monomers as shown in Table 1.

The polymer films were deposited at a glassy carbon electrode using successive cycling between -0.4 to 1.2 V vs. SCE at 50 mV s^{-1} . From Fig. 1 we can see that all CVs show redox peaks characteristic for the co-polymer formation and the current increases with each consecutive cycling, which indicates an increase in the amount of deposited polymer. At the same time homogeneous and adherent polymer films were deposited on the anode surface, which can

be observed by the naked eye. In our previous work [34] we have shown that the polymerization of EDOT, ANI and its co-monomers produce a binary mixture consisted of a blend of PANI and PEDOT-PANI co-polymers.

Also as shown in fig.1 (c – f) the trace-crossings appear on the reverse sweeps of the first cycle in voltammograms for solutions contains $X_{ANI} = 0.5$ to 0.9. This interpreted as the additional anodic current observed in the reverse sweep results from slow follow-up reactions occurring in the diffusion layer in front of the electrode, that in case of $E(CE)_n$ reactions involve slow rate constants for chemical step [35]. A

high proton activity generally diminishes the tendency to lose protons from cation radical; as a result, in case of high ANI ratio slow second-order coupling steps between dimmers and subsequent slow elimination of protons explain the observed trace-crossings.

The electrocatalytic effect of SDS was characterized by a significant decrease of the EDOT oxidation potential in the micellar medium relative to acetonitrile as well as aqueous solutions. This behaviour might result from strong electrostatic interactions occurring between the $EDOT^{\bullet+}$ radical cations and the dodecylsulfate anions during the polymerization process [36].

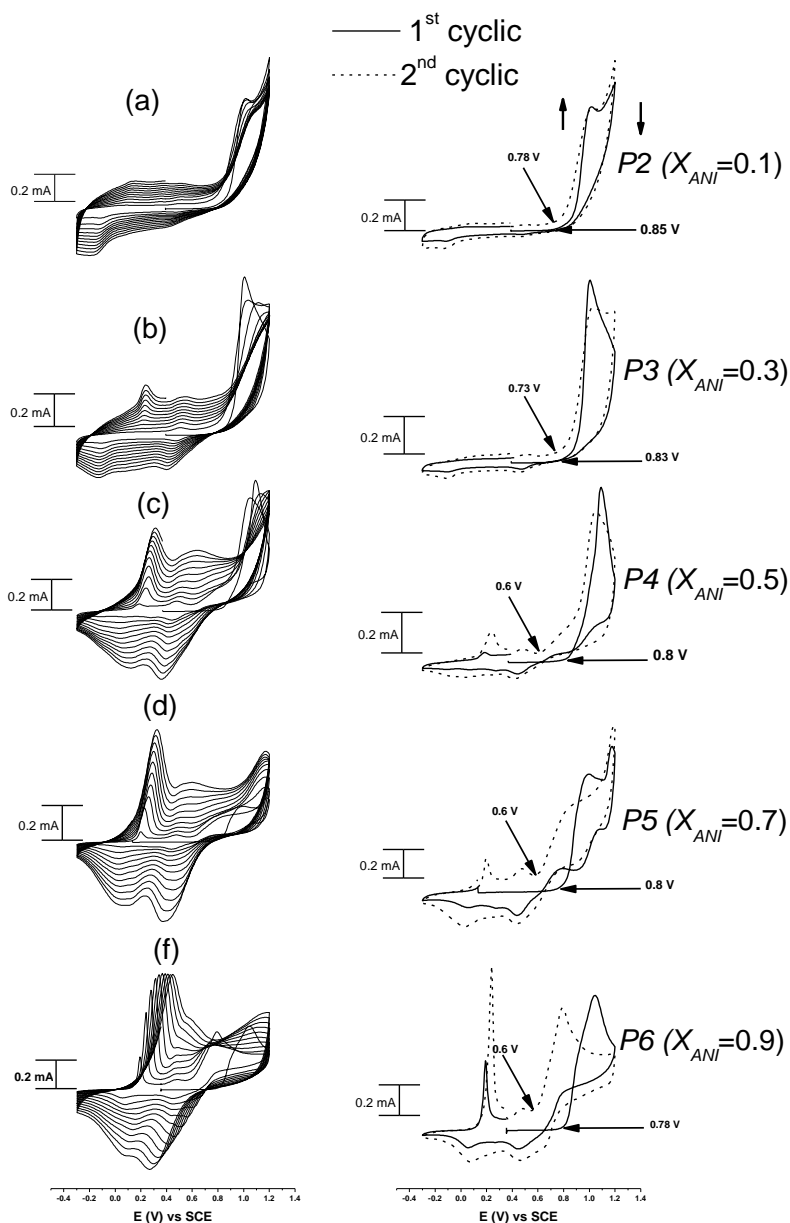


Figure 1 - Cyclic voltammograms at 50 mV s^{-1} for GC electrode in 70 mM SDS and $0.5 \text{ M H}_2\text{SO}_4$ and containing (a) $35 \text{ mM EDOT} + 15 \text{ mM ANI}$, $X_{ANI} = 0.3$, (b) $25 \text{ mM EDOT} + 25 \text{ mM ANI}$, $X_{ANI} = 0.5$, (c) $15 \text{ mM EDOT} + 35 \text{ mM ANI}$, $X_{ANI} = 0.7$, (d) $5 \text{ mM EDOT} + 45 \text{ mM ANI}$, $X_{ANI} = 0.9$.

The presence of the hydrophobic (micellar core) and hydrophilic interface in normal micellar solution may induce an orientation of reactants in micelles, which in turn affects the regioselectivity of reaction and reaction kinetics [37]. When the reaction is performed in microemulsion the anilinium cation would be oriented and accumulation of aniline at the oil-water interface, with the amino group oriented into the water phase [38]. We suggested that under the influence of the electric field the hydrophilic interface in micelles containing aniline will be attracted and oriented at the anode surface as is illustrated in Fig. 2. This facilitated the accumulation of anilinium cation at the anode surface and hence decreasing polymerization potential of co-monomers on GC surface from 0.85V at $X_{ANI}=0.1$ to 0.78V at $X_{ANI}=0.9$ as shown in Fig.1.

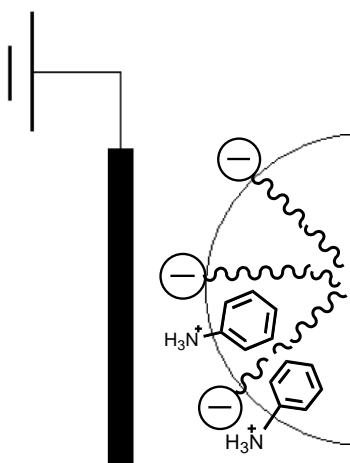


Figure 2 - The hydrophilic interface in micelles containing aniline will be attracted and oriented at the anode surface [33].

In the case of polymer-surfactant interactions, individual surfactant molecules and polymer chain interaction or polymer aggregate may occur. This leads to a complex formation between the polymer chain and micelles or pre-micellar aggregates. There can be also a formation of hemimicelles, structures with characteristics of micelles but intimately associated with the locus of formation, along the chain due to other associations. SDS may be loosely bound to the formed polymer matrix and leaches out during cycling, thus leaves behind a porous film. This porous layers make the facilitate formation of more polymer during cycling and decrease the polymerization potential.

Fig. 3 shows the SEM micrograph for the P5 (EDOT-ANI) polymer surface. Clearly we can see the polymer surface exhibits flakes porous interconnected structures which promote the efficient contact between the active material and the electrolyte, providing many active sites for electrochemical reactions.

Structures with porosity and interconnectivity supply additional accessible space for ions, while maintaining sufficient conductivity for solid-state electronic transfer to improve the electrochemical capacity. This type of structure provides a short diffusion path length to both ions and electrons and also sufficient porosity for electrolyte penetration to increase charge/discharge rates.

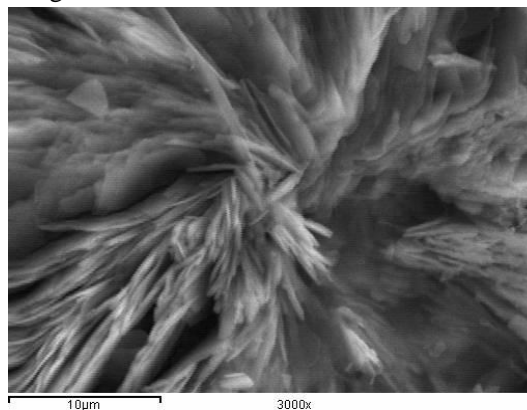


Figure 3 - Scanning electron micrographs of P5 copolymer films deposited using successive cycling between -0.4 to 1.2 V vs. SCE at 50 mV s^{-1} , 3000 time magnification.

3.2. Pulse Electropolymerization of ANI and EDOT mixed monomers.

The PANI-PEDOT co-polymer films were obtained by passing total charge of 60 mC using chronopotentiometric (DC) and pulsed polymerization technique from solution containing both monomers with $X_{ANI} = 0.7$, 0.5 M H_2SO_4 as supporting electrolyte and 70 mM SDS as surfactant. The DC polymerization was carried out by applying 0.4 mA for 150 s. Pulse polymerization was carried out by applying constant current 0.4 mA for a very short period of time, pulse on time was varied from 10 ms to 1 s and pulse off time was chosen as constant 100 ms no current was applied during the off period.

Fig. 4 shows the relation between the voltage and time at constant current of 0.4 mA for solution containing $X_{ANI} = 0.7$ ANI, 0.5 M H_2SO_4 as supporting electrolyte and 70 mM SDS as surfactant.

The data clearly show that the polymerization voltage was increased with time up to 2V in case of DC polymerization which reflects the electrochemical inhibition of the obtained polymer film by highly oxidizes polyaniline form pernigraniline (insulator), also in pulse on times 0.1s and 1 s the polymerization voltage increase up to 2V, where in case of very short pulse on time 10 ms the polymerization voltage varied between 0.7 and 0.8 V which indicates that the polymer formed at pulse on 10 ms is more reactive than that formed at 0.1 or 1 s.

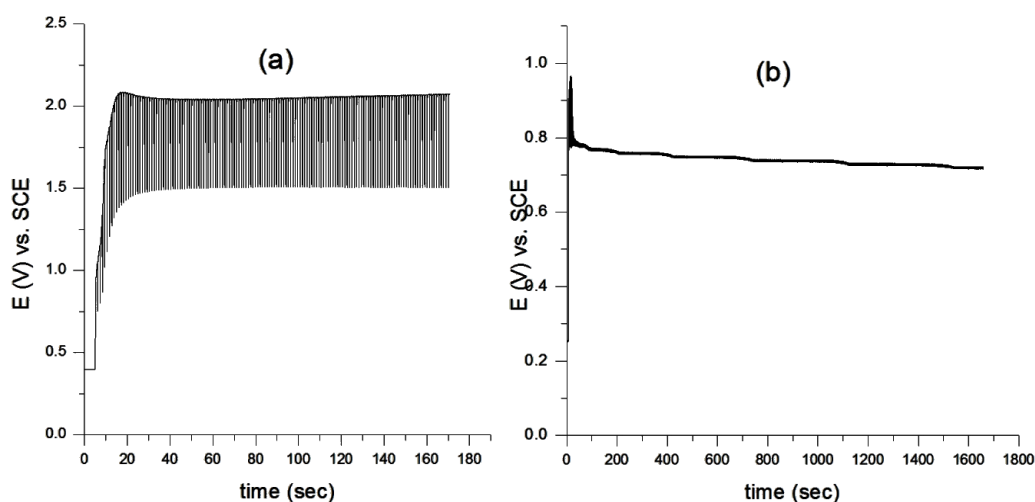


Figure 4 - Chronopotentiometric response of EDOT and ANI electropolymerization on GC electrode in 0.5 M H₂SO₄ and 70 mM SDS micellar solution containing 15 mM EDOT + 35 mM ANI. The applying charge is 60 mC (a) Pulse polymerization pulse on time 1 s, and (b) pulse on time 0.001 s, respectively.

The application of ultra short current pulse, 10 ms, has definite effect on the polymer structure and the chain length is obviously short in comparison to DC electrochemical method of polymerization. Moreover the short polymer chains are the ideal structures for many applications such as supercapacitor [39]. During the pulse on, the current allows polymer chain to nucleate over the substrate surface only for a very short period followed by the off time pulse that do not initiate fresh nucleation but terminate the chains growing. In addition in case of very short pulse on time there is no more oxidation for obtained PANI to highly oxidize polyaniline form (pernigraniline). Relatively longer off time help the already grown chains to oxidize completely and oriented over the surface with fullest conjugation before the next pulse charges and another polymer chain nucleates over [40]. During the off pulse the growth on the initial sites of the electrode is terminated. During the next on pulse the growth on the fresh sites of the electrode is predominant, consequently a large number of equivalent nucleation and growth sites formed [41]. Therefore the PANI-PEDOT co-polymer obtained from short pulse on time (10 ms) are supposed to have shorter polymer chain length, higher degree of conjugation and complete orientation in oxidized state.

Fig. 5 shows the morphology of the as-prepared P5 (PANI-PEDOT co-polymer) films deposited by both chronopotentiometric and pulse polymerization technique analyzed using SEM. The polymer surface characterization using SEM confirm that the pulsed PANI/PEDOT deposits at first as a thin layer followed by rough and nodular growth which results

in an open and porous structure, where DC PEDOT/PANI grows as a smooth and dense film.

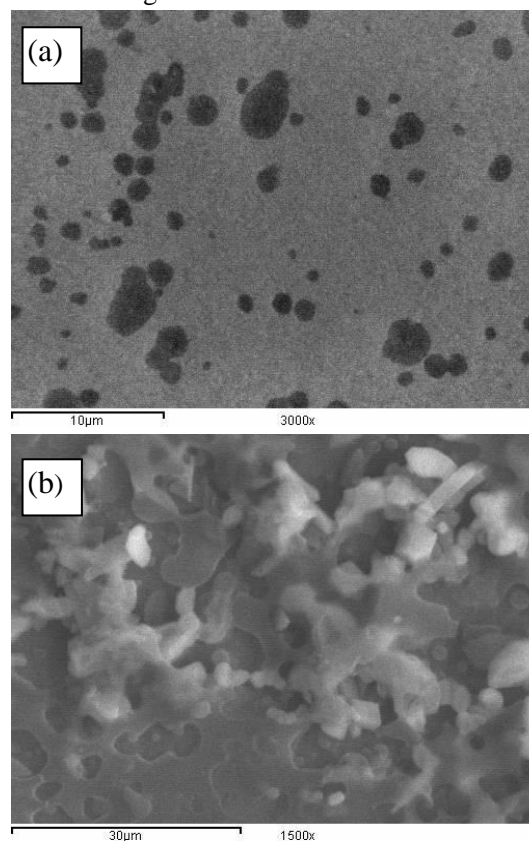


Figure 5 - Scanning electron micrographs of the P5(ANI-co-EDOT) film (a) DC polymerized film at 0.4 mA for 150 s. (b) Pulse polymerized film; pulse on current 0.4 mA, pulse off time 100 ms and pulse on time = 1 ms. Total polymerization charge was 60 mC.

3.3. Electrochemistry of co-polymer films obtained from cyclic voltammetry.

Fig. 6 a–f shows the cyclic voltammograms at 100 mVs^{-1} in $1.0 \text{ M H}_2\text{SO}_4$ for the co-polymer films electrodeposited by cyclic voltammetry from micellar solutions contain different mole fraction of ANI and EDOT as shown in Table 1.

Curve (Fig.6a) show rectangular like and symmetric voltammograms, demonstrating the good capacitive behaviour of these electrode materials. For the

curves (Fig.6 b-f), the voltammetric curves exhibit anodic and cathodic peaks that characteristic of PANI doping-dedoping behaviour.

The peak current gradually increases and the anodic peak potentials shift regularly to more positive values as the X_{ANI} is increased. Also a liner relationship between peak potential and X_{ANI} was observed as shown in Fig. 7. This reflects the increase in the amount of PANI deposited in the polymer film.

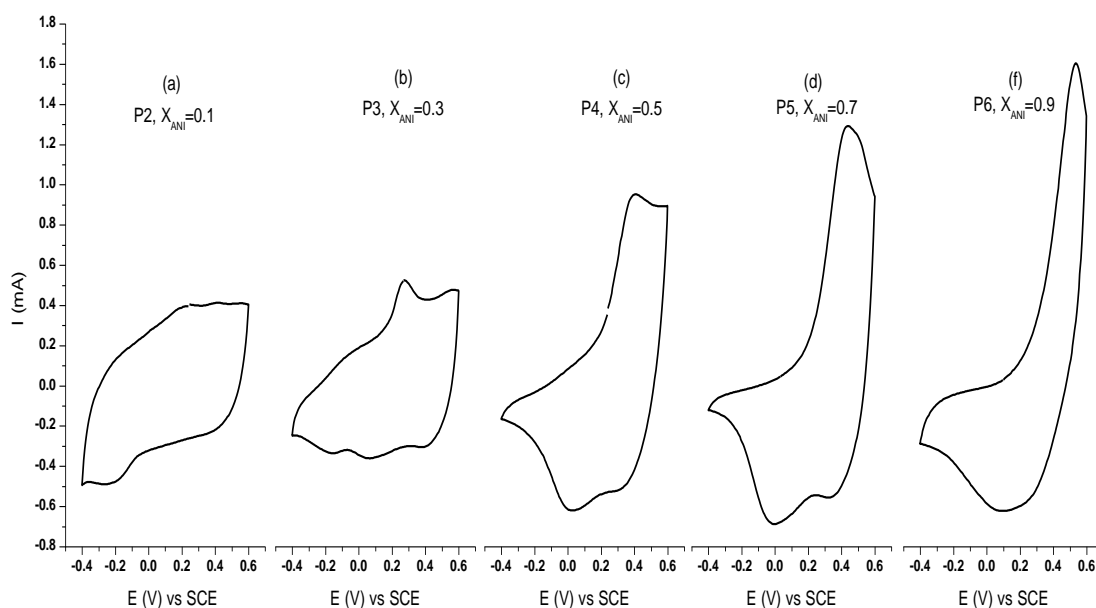


Figure 6 - Cyclic voltammograms at 100 mVs^{-1} obtained for co-polymer films in $1.0 \text{ M H}_2\text{SO}_4$, (a) $X_{\text{ANI}} = 0.1$, (b) $X_{\text{ANI}} = 0.3$, (c) $X_{\text{ANI}} = 0.5$, (d) $X_{\text{ANI}} = 0.7$ and (f) $X_{\text{ANI}} = 0.9$.

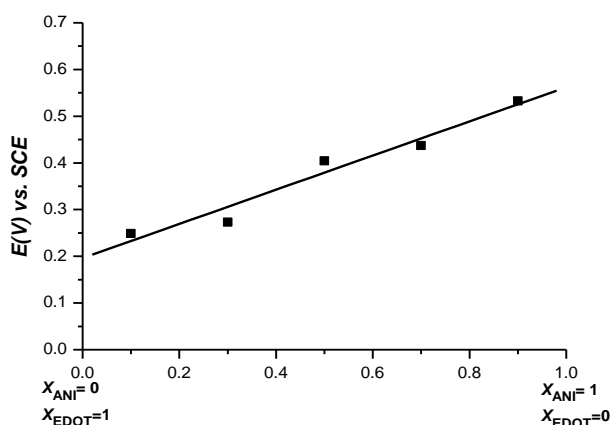


Figure 7 - Relationship between anodic (E_a) peak potential and mole fraction of the obtained polymer films from solution contain different EDOT: ANI ratio, in $1.0 \text{ M H}_2\text{SO}_4$ solution.

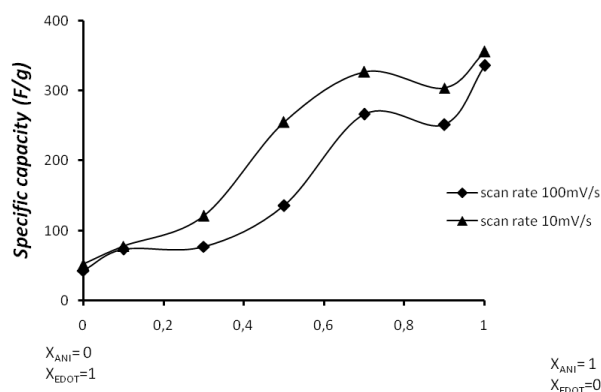


Figure 8 - Relationship between specific capacity and aniline mole fraction measured in $1.0 \text{ M H}_2\text{SO}_4$ for the co-polymer films electrodeposited by cyclic voltammetry

It appears that all the redox peaks overlap with that of PEDOT rectangular like capacitance and became slightly larger with increasing X_{ANI} .

Fig. 8 shows the relation between specific capacitance and X_{ANI} at different scan rate scan rate in 1.0 M H_2SO_4 . Increasing X_{ANI} enhance the specific capacity of the obtained co-polymers, (Fig. 8) and specific capacitance reaches up to 327 Fg^{-1} for the co-polymer P5(PANI-PEDOT) at 10 mVs^{-1} . Clearly and as shown in Fig. 8, increasing scan rate decrease the specific capacity.

Table (2) shows the capacitance decrease after 300 cyclic for co-polymers films measured in 1.0 M H_2SO_4 at 100 mVs^{-1} . The PANI/PEDOT co-polymers (P3 to P6) clearly have much more electrochemical stability than the pure PANI (P7) and PEDOT (P1) where the co-polymer composite retains about 90% of the original capacitance value after 300 cycles.

This electrochemical stability may reflect the affinity between the oxidized PEDOT and PANI. So a large amount of active material is still available after cycling which results in improved electrochemical stability.

Table 2 - Effect of repeating cycling on the capacitance of co-polymers films measured in 1.0 M H_2SO_4 at 100 mVs^{-1} .

	X_{ANI}	Specific capacitance after second cycle (Fg^{-1})	Specific capacitance after 300 cycles (Fg^{-1})	Specific capacitance decrease after 300 cycles (%)
P1	0.0	43.01	35.08	18.44
P2	0.1	73.26	61.53	16.01
P3	0.3	77.10	70.40	8.70
P4	0.5	135.95	122.67	9.77
P5	0.7	266.36	237.95	10.67
P6	0.9	251.45	230.71	8.25
P7	1	336.10	297.76	11.41

The capacitive and stability properties of the resulting co-polymers were also studied in neutral solution of 1.0 M NaCl. Table 3 shows the specific capacitance of the co-polymer films in 1.0 M NaCl calculated using the second cycle and at 100 mVs^{-1} . The capacitance in 1.0 M H_2SO_4 is shown for comparison.

Table 3 - Specific capacitance of co-polymers films in 1.0 M H_2SO_4 and 1M NaCl at 100 mVs^{-1} .

	X_{ANI}	Specific capacitance after second cycle (Fg^{-1}) in 1.0 M H_2SO_4	Specific capacitance after second cycle (Fg^{-1}) in 1.0 M NaCl	Specific capacitance decrease in 1.0 M NaCl (%)*
P1	0.0	43	41	4.6
P2	0.1	73	67	8.5
P3	0.3	77	76	1.4
P4	0.5	136	133	2.1
P5	0.7	266	263	1.2
P6	0.9	251	210	16.4
P7	1	336	240	28.5

$$*\text{Specific capacitance decrease in 1.0 M NaCl (\%)} = \frac{\text{Specific capacitance in 1.0 M } H_2SO_4 - \text{Specific capacitance in 1.0 M NaCl}}{\text{Specific capacitance in 1.0 M } H_2SO_4} \times 100$$

Interestingly the results show that the co-polymers (P3 to P5) show a high stability in neutral NaCl solution where a very small decrease ($\cong 2\%$) in specific capacity was observed. On the other hand as the ANI mole fractions increases (P6 and P7) the specific capacity decreases by about 28% in neutral solution in comparison with that from acidic solution. The redox process of electroactive polymer generally consists of two aspects; the charge that transferred is delocalized over a few molecular units and this charge is compensated by inclusion of oppositely

charged ions in the polymer matrix. For PANI the redox reaction involves protons, where the PANI oxidation accompanied by the protonation of the imine nitrogen which produces the conducting state and this protonation is reversible. This unexpected specific capacity for the obtained polymer composites in neutral solution may be attributed to the oxidized state of PEDOT unites in the composite co-polymer act as Lewis acid which enhance the oxidation of PANI unites.

3.4. Capacitive behaviour of PEDOT/PANI obtained from different deposition technique.

Fig. 9 shows the cyclic voltammograms at 100 mVs^{-1} for the co-polymer P5(PANI-PEDOT) films measured in $1.0 \text{ M H}_2\text{SO}_4$ and deposited by passing the same deposition charge using both chronopotentiometric and pulse polymerization technique. It is remarkable that although the growth charge for both the polymer films is same the specific capacity in $1.0 \text{ M H}_2\text{SO}_4$ for the pulse polymerized co-polymer reaches 290 Fg^{-1} while the DC polymerized electrode has specific capacitance of 14 Fg^{-1} .

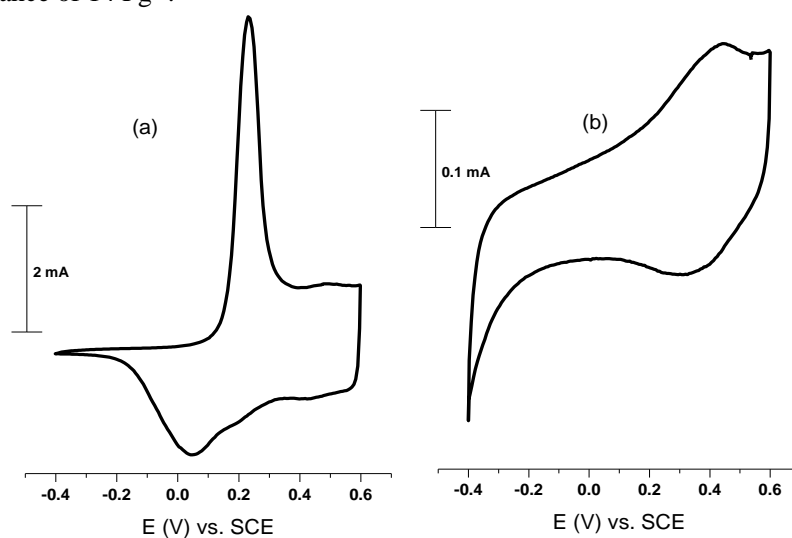


Figure 9 - Cyclic voltammograms at 100 mVs^{-1} in $1.0 \text{ M H}_2\text{SO}_4$ for Co-polymer films (a) Pulse polymerization by applying constant current 0.4 mA , 10 ms pulse on time. (b) DC polymerization by applying 0.4 mA for 150 s . Total deposition charges was 60 mC .

Also as discussed previously in section 3.2 the potential during DC polymerization was about 2 V where during the shorter pulse deposition the potential was about 0.7 V (Fig. 4). Thus we can conclude that the co-polymer film obtained from the DC polymerization was deactivated at this high voltage where there is no deactivation noted for the film prepared by short pulse deposition.

4. CONCLUSION

Electrochemical capacitance and stability properties for different molar ratios of PANI/PEDOT co-polymer electrodes were investigated in acidic and neutral solution. Increasing X_{ANI} enhance the specific capacity of the EDOT where the rod like morphology was formed in case of composite electrodes. Using pulse polymerization technique with short pulse on time 10 ms enhance the specific capacity of the composite polymer electrode and give much higher specific capacitance than one obtained from DC polymerization. The obtained polymer composites have good cycling stability in acidic solution, where it retains 90% from original specific capacity

From the SEM polymer surface characterization shown in Fig.5, we can note that pulsed PEDOT/PANI deposits at first as a thin layer followed by rough and nodular growth which results in an open and porous structure and that reflect the high specific capacity of 290 Fg^{-1} . While in DC case the PEDOT/PANI grows as a smooth and dense film which have very high resistance for ion transfer and also formation of highly oxidized polyaniline (pernigraniline form) therefore the obtained polymer film have very low specific capacity of 14 Fg^{-1} .

value after 300 cycles in $1.0 \text{ M H}_2\text{SO}_4$ at 100 mVs^{-1} . The polymer composites show improved capacitance stability in neutral solution (1.0 M NaCl) as well as in acidic solution which reflects the synergism between PANI and PEDOT in the obtained polymer composite.

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IZVOD

SUPERSKAPACITIVNA SVOJSTVA ELEKTROPOLIMERIZOVANIH POLI(3,4-ETILENDIOKSIFENE) I POLI(ANILIN) CO-POLIMERSKIH ELEKTRODA

U ovom radu ko-polimer od polianilina (PANI) i poli (3,4-etilendioksitofen) PEDOT filmovi sa različitim molarnim odnosom (MR) su elektrohemijski deponovani putem ciklične voltametrije i struja kratkog impulsa elektrodi od staklastog micelarnog ugljenika.

Morfologija površina nastalih ko-polimernih filmova karakterisana je elektronskim mikroskopom a efekat molarnog monomera ispitan je korišćenjem ciklične voltametrije u kiselim i neutralnim rastvorima. Specifična kapacitivnost PEDOT-PANI ko-polimera dostiže i do 327F g⁻¹ i zadržava oko 90% od osnovne vrednosti posle 300 ciklusa u 1M H₂SO₄ na 10 mVs⁻¹. Prisustvo natrijum dodecil sulfata (SDS) poboljšava kapacitivnost polimera i smanjuje potencijal polarizacije monomera. Kompozitni polimeri pokazuju poboljšanu kapacitivnu stabilnost u neutralnom rastvoru 1M NaCl, kao i u kiselom rastvoru koji odražava sinergizam između PANI i PEDOT na depozitu ko-polimera.

Key words: *polimer, elektronska mikroskopija, superkapacitivnost, elektrohemijska ispitivanja.*

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